UNITED STATES PATENT AND TRADEMARK OFFICE

UNDER SECRETARY OF COMMERCE FOR INTELLECTUAL PROPERTY AND DIRECTOR OF THE UNITED STATES PATENT AND TRADEMARK OFFICE
WASHINGTON, DC 20231
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Paper No

Notice of Non-Compliant Amendment (37 CFR 1.121)

The amendment filed on 5-6-03 is considered non-compliant because it has failed to meet the requirements of 37 CFR 1.121, as amended on September 8, 2000 (see *65 Fed. Reg. 54603*, Sept. 8, 2000, and *1238 O.G. 77*, Sept. 19, 2000). In order for the amendment to be compliant, applicant must supply the following omissions or corrections in response to this notice.

THE FOLLOWING ITEMS ARE REQUIRED FOR COMPLIANCE WITH RULE 1.121 (APPLICANT NEED NOT RE-SUBMIT THE ENTIRE AMENDMENT):

☐ 1. A clean version of the replacement paragraph(s)/section(s) is required. See 37 CFR 1.121(b)(1)(ii).

☒ 2. A marked-up version of the replacement paragraph(s)/section(s) is required. See 37 CFR 1.121(b)(1)(iii).

☐ 3. A clean version of the amended claim(s) is required. See 37 CFR 1.121(c)(1)(i).

☐ 4. A marked-up version of the amended claim(s) is required. See 37 CFR 1.121(c)(1)(ii).

Explanation: The specification can't be renumber.

(LIE: Please provide specific details for correction to assist the applicant. For example, "the clean version of claim 6 is missing.")

For further explanation of the amendment format required by 37 CFR 1.121, see MPEP § 714 and the USPTO website at http://www.uspto.gov/web/offices/dcom/olia/pbg/sampleaf.pdf. **A condensed version of a sample amendment format is attached.**

☐ **PRELIMINARY AMENDMENT:** Unless applicant **supplies the omission or correction** to the preliminary amendment in compliance with revised 37 CFR 1.121 noted above within ONE MONTH of the mail date of this letter, examination on the merits may commence without entry of the originally proposed preliminary amendment. This notice is not an action under 35 U.S.C. 132, and this ONE MONTH time limit is not extendable.

☒ **AMENDMENT AFTER NON-FINAL ACTION:** Since the above-mentioned reply appears to be *bona fide*, applicant is given a TIME PERIOD of ONE MONTH or THIRTY DAYS from the mailing of this notice, whichever is longer, within which to **supply the omission or correction noted above** in order **to avoid abandonment.** EXTENSIONS OF THIS TIME PERIOD MAY BE GRANTED UNDER 37 CFR 1.136(a).

Irina Stepto

Legal Instruments Examiner (LIE)

(Rev. 12/01)

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No.	Doccode	Number of pages
1	SPEC	13
2	LET.	3

Total number of pages: 16

Remarks:

Order of re-scan issued on ....

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BACKFILE DOCUMENT INDEX SHEET

APPL PARTS

_________ IMIS _____
Internal Misc. Paper

_________ LET. _____
Misc. Incoming Letter

_________ 371P _____
PCT Papers in a 371Application

_________ A... _____
Amendment Including Elections

_________ ABST _____
Abstract

_________ ADS _____
Application Data Sheet

_________ AF/D _____
Affidavit or Exhibit Received

_________ APPENDIX _____
Appendix

_________ ARTIFACT _____
Artifact

_________ BIB _____
Bib Data Sheet

_________ CLM _____
Claim

_________ COMPUTER _____
Computer Program Listing

_________ CRFL _____
All CRF Papers for Backfile

_________ DIST _____
Terminal Disclaimer Filed

_________ DRW _____
Drawings

_________ FOR _____
Foreign Reference

_________ FRPR _____
Foreign Priority Papers

_________ IDS _____
IDS Including 1449

_________ NPL _____
Non-Patent Literature

_________ OATH _____
Oath or Declaration

_________ PET. _____
Petition

_________ RETMAIL _____
Mail Returned by USPS

_________ SEQLIST _____
Sequence Listing

8-9-08 SPEC 13
Specification

_________ SPEC NO _____
Specification Not in English

_________ TRNA _____
Transmittal New Application

_________ CTNF _____
Count Non-Final

_________ CTRS _____
Count Restriction

_________ EXIN _____
Examiner Interview

_________ M903 _____
DO/EO Acceptance

_________ M905 _____
DO/EO Missing Requirement

_________ NFDR _____
Formal Drawing Required

_________ NOA _____
Notice of Allowance

_________ PETDEC _____
Petition Decision

OUTGOING

_________ CTMS _____
Misc. Office Action

_________ 1449 _____
Signed 1449

_________ 892 _____
892

_________ ABN _____
Abandonment

_________ APDEC _____
Board of Appeals Decision

_________ APEA _____
Examiner Answer

_________ CTAV _____
Count Advisory Action

_________ CTEQ _____
Count Ex parte Quayle

_________ CTFR _____
Count Final Rejection

INCOMING

_________ AP.B _____
Appeal Brief

_________ C.AD _____
Change of Address

_________ N/AP _____
Notice of Appeal

_________ PA.. _____
Change in Power of Attorney

_________ REM _____
Applicant Remarks in Amendment

_________ XT/ _____
Extension of Time filed separate

Internal

_________ SRNT _____
Examiner Search Notes

_________ CLMPTO _____
PTO Prepared Complete Claim Set

_________ ECBOX _____
Evidence Copy Box Identification

_________ WCLM _____
Claim Worksheet

_________ WFEE _____
Fee Worksheet

File Wrapper

_________ FWCLM _____
File Wrapper Claim

_________ IIFW _____
File Wrapper Issue Information

_________ SRFW _____
File Wrapper Search Info

REV 7/02/03

~~CONDUCTED HEAT VECTOR SENSOR~~

BACKGROUND OF THE INVENTION

A common requirement in molding and casting processes is to measure the flow of heat from the molded or cast object, through the body of the mold to a liquid coolant or to the outside air. This is a difficult measurement to make, because:

1. most molding and casting processes involve very high temperatures;
2. the casting or molding process environment is extremely dirty, often electrically noisy;
3. molds are typically made of solid metal with high thermal conductivity; and
4. typical commercially available heat flux sensors have low thermal conductivity.

U.S. Patent 5,360,051, issued to Takahashi et al, describes a typical requirement for heat flux measurements in a continuous casting process. The solution offered by the patentee is to embed thermocouples in the wall of the mold. Heat flux through the mold may be calculated from the signals of these thermocouples, which indicate temperatures of the mold body at various points. Heat flux is calculated using measured or assumed values of the mold's thermal properties.

An alternative to the thermocouples of Takahashi et al would be a plug-type heat flux sensor as described by Liebert et al in U. S. patents 5,048,973, 5,086,204 and 5,314,247. The sensor described in these patents is an isolated plug directly machined into the wall of a vessel, optimally by electro-discharge machining, with thermocouples placed at various depths on the outer surface of the isolated plug. Heat flux is calculated from temperature data derived from the thermocouples, using a temperature variant thermal property inverse heat conductive problem method. These calculations of heat flux are extremely susceptible to electrical noise in the thermocouple signals. Any error in locating the thermocouples on the plug surface translates directly into an error in the heat flux calculation. The insulating gap between the instrumented

plug and the surrounding material allows the plug temperature profile to depart from that in the surrounding material, depending on conditions at the open end of the plug. This can produce large errors.

An alternative to these methods would be to apply heat flux sensors to the surface of the mold. Such sensors are described in U. S. Patent 4,567,365 issued to Degenne, U. S. Patent 5.990,412 issued to Terrell, and U. S. Patent 6,278,051, issued to Peabody. Heat flux sensors based on the teaching of these patents are commercially available, but they are not suitable for measurements in molding and casting processes. Their attachment to the outer surface of a mold adds a large local thermal resistance which causes heat to be shunted around the area covered by the sensor. The resulting measurements may be inaccurate as well as sensitive to local air currents and other conditions, and the sensors themselves are vulnerable to damage.

Ideally the flow of heat in a casting or molding process would be measured by a thermopile-type heat flux sensor imbedded in the mold itself. However, if the thermal conductivity of such a sensor were greatly different from that of the surrounding material, the pattern of heat flow through the mold would be distorted in the region of the sensor. This would produce a systematic error in the heat flux measurement. Thus it would be important for the sensor's thermal conductivity to nearly match that of the mold. Also, voids or air spaces could not be introduced into the mold when the sensor is installed, because these would produce even more serious distortions of the heat flow in the region of the sensor.

The conventional way to achieve good noise immunity for a thermopile-type heat flux sensor is to raise its output voltage by increasing the temperature drop it introduces into the heat flow path. While this approach is acceptable in radiative heat flux measurements, it cannot be used for conductive heat flux measurements because of the large error it produces. When the thermal conductivity of an imbedded sensor is made approximately equal to that of the mold, the only ways to increase the heat flux signal are by increasing the number of thermocouple pairs or by increasing their physical separation in the direction of heat flow. Space is not often available for

the large sensor that would be required.

U. S. Patent 4,779,994, issued to Diller et al, teaches the application of a thin film thermopile heat flux sensor to a surface, for measurement of convective or radiative heat flux through the surface. The output voltage of these sensors is small despite their construction with hundreds of thermocouple pairs, because the thermal resistance they place in the path of heat flow is extremely small. Typically the resistive element consists of one micron (10^{-6} meter) of a ceramic such as silicon monoxide. The thin films of these sensors are vulnerable to damage by abrasion and chemical attack, so they would not be suitable for the molding and casting environment.

SUMMARY OF THE INVENTION

A sensor designed for measurement of conducted heat flux passing through a solid object consists of a thin film thermopile deposited on a plane surface of a thin rectangular substrate. The thermopile is protected by being covered by a thin rectangular plate of the same material as the substrate. The sensor fits tightly in a slot in a threaded plug. For a measurement of heat flux in the solid object the threaded plug is imbedded in the solid object. Thermal properties of the substrate, the plate and the threaded plug match those of the solid object. When heat flows through the solid object the output voltage of the thermopile indicates the magnitude of the heat flux vector along the thermopile axis. Because the thermal properties of the substrate, plate and plug match those of the solid object, there is minimal deviation of the heat flow pattern from that which would have existed without the sensor present.. Accurate and precise measurements of heat flux are the result. Applications include measurement of heat flux in casting molds, boiler tubes, well surveying instruments and laser weapons testing.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a system for measuring the heat flow in a solid body such as a metal casting

mold. Figure 2 is a sectional view of a conductive heat transfer sensor installed in a threaded hole in a mold. Figure 3 is a sectional view of a sensor. Figure 4 shows details of the threaded body of the sensor. Figure 5 shows tools for opening the slot in the sensor body to install the sensing substrate and cover, and for tightening the sensor in its blind threaded hole in the mold. Figure 6 shows the sensing insert, consisting of two flat plates fabricated from an electrically insulating material. Figure 7 shows the lower plate, with its heat flux sensing pattern of thermocouples. Figure 8 shows the upper plate that protects the sensing pattern from abrasion and chemical attack.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION

Referring now to Figure 1, a system 1 for measuring heat flow in a solid body is shown, consisting of a conductive heat transfer sensor 2 and a voltage indicating meter 3, with interconnecting wires 4 and 5. The sensor 2 is installed in a blind hole in a casting mold 6 to measure heat transfer in the body of the mold. The sensor produces a voltage that is proportional to the rate of heat flow per unit area in the direction of the sensor axis 7. This voltage is indicated by the meter 3, whose scale may be graduated in conventional heat flux units such as watts/cm^2 or BTU/ft^2-sec. In the preferred embodiment of the invention, the thermal conductivity and thermal diffusivity of the sensor materials are nearly equal to corresponding values for the material of the mold itself. When this is so, insertion of the sensor 2 does not change the amount or pattern of heat flow in the mold, and an undisturbed, accurate measurement of heat flow is achieved.

Figure 2 shows how the conductive heat transfer sensor 2 fits into the blind threaded hole 8 in the mold 6. In the preferred embodiment, the hole 8 has a flat bottom 9, and the end 10 of the sensor 2 is also flat. This arrangement results in an area contact between the end of the sensor and the bottom of the hole, facilitating heat transfer from the mold to the sensor with minimum temperature drop. It also minimizes the air space at the end 10 of the sensor.